

## **APPENDIX B: INTERPRETATION OF SPECTRUM SURVEY DATA**

### **B.1 INTRODUCTION**

Institute for Telecommunication Sciences (ITS) radio spectrum measurement system (RSMS) spectrum survey measurements are performed with a variety of receiver algorithms (see Section D.2 of Appendix D). These algorithms provide various combinations of frequency-sweeping or frequency-stepping, positive-peak or sample detection, and data-processing capabilities during the data acquisition phase of the spectrum survey. Additional processing is performed on the data after the acquisition phase. Measurement algorithms are assigned on an individual basis to optimally measure spectrum use in each band.

Each algorithm has a particular response to noise and signal activity. It is critical to understand the noise and signal response of each algorithm if the RSMS data are to be used accurately. This appendix describes the algorithms currently used for RSMS spectrum surveys. The noise and signal response of each algorithm is described, along with the types of spectrum occupancy it is best suited to measure. Some of the data-processing techniques also are discussed to fully explain the measurement algorithms.

### **B.2 SIGNAL PROBABILITY-OF-INTERCEPT FACTORS**

RSMS measurements are intended to achieve a high probability of intercept for the types of signal activity occurring in each spectral band. Factors that are considered include:

- ▶ the types of emitters allocated to the band (e.g., land mobile radio, radiolocation, or broadcasting);
- ▶ the percentage of time individual transmitters in the band typically operate (e.g., 100% on-air time by broadcasters vs. intermittent radio dispatch messages);
- ▶ the dependence (or nondependence) of band activity on diurnal and other cyclic occurrences (e.g., radionavigation beacons with no time dependence vs. marine mobile activity which varies as a function of time of day, day of week, and weather conditions);
- ▶ the time interval that individual transmissions usually occupy (e.g., air traffic control communications vs. cellular telephone communications);
- ▶ the periodicity, if any, of individual transmissions (e.g., a highly periodic search radar beam that completes a rotation every 4 s vs. mobile communications that occur in a random distribution over time);
- ▶ the directional gain, if any, of antennas used by the transmitters (e.g., an omni-directional navigation beacon vs. a point-to-point microwave link);

- ▶ the typical peak and average power outputs of transmitters in the band (e.g., 4-MW peak power from a radar vs. a fraction of a watt from a personal cellular telephone);
- ▶ the signal amplitude duty cycle (e.g., a 30-dB duty cycle for a typical radar vs. a near 0-dB duty cycle for a two-way radio transmission);
- ▶ the relative abundance or paucity of systems using the band (e.g., a band used largely by airborne fire-control radars vs. a band used by thousands of local voice-communication radios); and
- ▶ the polarization of typical transmitted signals in the band.

These factors are used to optimize the receiver parameters for the selected band, to select the measurement algorithm, and to determine how measurement time should be allocated. The relative amount of time devoted to measure each band is roughly proportional to the dynamics of band usage. For example, point-to-point microwave bands are not very dynamic because the transmitters in these bands normally operate 24 hrs/day, 365 days/year, at uniform power levels, fixed modulations, and fixed beam directions. Their operations are not normally affected by external factors, such as weather or local emergencies. Consequently, these bands are measured only once during a spectrum survey. In contrast, activity in land mobile radio bands is highly dynamic, varying significantly with time of day, day of week, and other factors such as local emergency conditions. Consequently, these bands are measured frequently throughout a site survey, so that a maximal number of time-dependent signals will be intercepted. Slightly less dynamic bands, such as those used by tactical radars, are measured less frequently than the mobile bands, but more frequently than the point-to-point microwave bands. Bands whose use varies with local weather, such as those used by weather radars, may be measured on different clear-weather and foul-weather schedules.

Swept-spectrum measurement techniques are used in highly dynamic bands. Stepped-spectrum techniques are used in bands occupied by periodic emitters, such as radars. A slow-rotating dish antenna sweep of the horizon coupled with simultaneous swept-spectrum measurements is used in point-to-point microwave bands. These measurement techniques are detailed in the following subsections.

A parabolic antenna is used to measure signals from fixed-beam, highly directional transmitters in the point-to-point microwave bands (see the description of azimuth scanning in Section B.8). For bands in which signals are expected to originate primarily from a single quadrant as seen from the RSMS location, a moderately directional antenna (such as a cavity-backed spiral or a log-periodic antenna) is used. For bands in which signals are expected to originate from any direction with an approximately constant probability, such as bands used by airborne beacon transponders and air-search radars, the RSMS uses omnidirectional antennas.

Slant polarized antennas are used for all RSMS measurements except those in the point-to-point microwave bands. Slant-polarized biconical omnidirectional antennas are usually used for measurements at frequencies above 1 GHz, and slant-oriented log-periodic or conical

omnidirectional antennas are usually used below 1 GHz. Slant polarization provides adequate response to all signals except those having a slant direction orthogonal to the RSMS antennas. Orthogonally oriented slant-polarized signals are rare. In the point-to-point microwave bands, the transmitted signals are always vertically or horizontally polarized, and thus RSMS receive polarization in those bands is alternately vertical and horizontal, with the results being combined into a composite scan.

The end result of these selections (number of measurements made in each band, selection of antenna type and polarization, and selection of measurement algorithm) is to optimize the probability of intercept for signals present during the course of the RSMS site survey. Inevitably, some signals will be missed; however, the standard RSMS spectrum survey data set should provide a statistically useful measure of the relative number, levels, and types of signals in each of the bands between 108 MHz and 19.7 GHz.

### **B.3 OVERVIEW OF SWEPT MEASUREMENT TECHNIQUES**

The HP-8566B spectrum analyzers<sup>1</sup> used in the RSMS sweep across the spectrum in individual segments that are called spans. The frequency range of each span is in turn broken into 1001 individual frequency bins. When the spectrum analyzers perform sweeps across a selected span, they spend a finite amount of time measuring received power in each of the 1001 bins. For example, a 20-ms sweep time divided by 1001 measurement bins per sweep yields a 20- $\mu$ s measurement time in each frequency bin. Within each bin measurement interval (in this example, 20  $\mu$ s), the power measured in the waveform may take on multiple values. However, the spectrum analyzer can only provide a single power measurement per bin.

The single value derived from the multiple values occurring within each bin-sampling interval depends upon the particular spectrum analyzer detector mode selected. The modes available in the RSMS spectrum analyzers are positive peak, negative peak, sample, and "normal." (Note: positive peak detection is different from the maximum-hold display mode discussed in Section B.6.) Positive peak detector mode will latch to the highest power value attained by the measured waveform during the sampling interval (continuing the example above, this would be 20  $\mu$ s) for each bin. Similarly, the negative peak detector mode latches to and displays the lowest power level measured during each bin interval. In sample detector mode, the value displayed is the power level that the input waveform has assumed at the end of the bin measurement interval. If the bin sampling interval is uncorrelated with respect to the input waveform, this value can be considered to be randomly selected from the input waveform. Finally, in "normal" detection mode, alternate bins use positive peak and negative peak detection.

If the analyzer's video bandwidth is substantially narrower than the IF bandwidth, and if a white noise source (such as thermal electron noise in a circuit or a noise diode) is being measured, then

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<sup>1</sup>Commercial equipment is identified to accurately describe the RSMS measurements. Such identification implies neither an endorsement by NTIA nor a recommendation that the equipment is best for the application.

an average value of the noise will be displayed irrespective of the detector mode that has been selected.

If the analyzer's video bandwidth is equal to or greater than the IF bandwidth, and if a white noise source is being measured, then the displayed power level will vary as a function of the detector mode. Positive peak detection will display noise values approximately 10 to 12 dB higher than the RMS noise level, and negative peak will display values about 10 to 20 dB below the RMS noise level. "Normal" detection used on such a noise source will display an illuminated band about 20 to 30 dB wide, with an average value approximately equal to the RMS level of the noise. Normal detection mode is useful for estimating the variability of a signal.

### **B.3.1 Description of the Swept/m3 Measurement Algorithm**

The swept/m3 algorithm, developed by ITS, is an extension to the swept measurements just described. In swept/m3 mode, frequency-domain data traces are measured repeatedly across a band on the spectrum analyzer. Each sweep is returned individually to the control computer, but the data traces are not individually recorded. Instead, for each of the 1001 frequency bins that the analyzer returns in each sweep, the computer sorts the returned values as follows: the value in each bin is compared to the highest and lowest values so far observed in that bin, and if the new value represents a new maximum or minimum in that bin, then it is saved as such. (This is, in effect, a software-implemented version of maximum-hold and minimum-hold trace mode.) Also, the current value of each bin is included in a running average of all the values returned for that bin in previous sweeps. This is an average of measured power in the selected detector mode (i.e., the decibel values are averaged). Thus, the maximum, minimum, and mean (m3) signal levels in a band are simultaneously obtained over the time interval (typically several minutes) that the spectrum analyzer continues sweeping. This real-time cumulative (cuming) process compresses data volume by several orders of magnitude, but the compression causes loss of the original data sweeps, and thus precludes the possibility of processing the original data sweeps with different algorithms during postmeasurement analysis. Figure B-1 shows how the swept/m3 cumulative processing is integrated with the normal RSMS processing path. All other cumulative processing is accomplished during postmeasurement analysis.<sup>2</sup> In the diagram, all measured data identified as "RSMS data output for lab analysis" is considered to be postmeasurement data.

## **B.4 DESCRIPTION OF SWEPT/M3/SAMPLE DATA COLLECTION**

If the swept/m3 algorithm (described in Subsection B.3.1) is performed using the sample detector (see Section B.3 for a description of the sample detector in the RSMS analyzers), then the data are referred to as "swept/m3/sample."

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<sup>2</sup>All band events measured more than once during the same survey are cumulated (cumed) as explained in this appendix. Stepped and swept data records are cumed for maximum, mean, and minimum received signal levels. Swept/m3 data already contains this information, so a maximum of maximums, mean of means, and minimum of minimums is extracted for survey graphs.

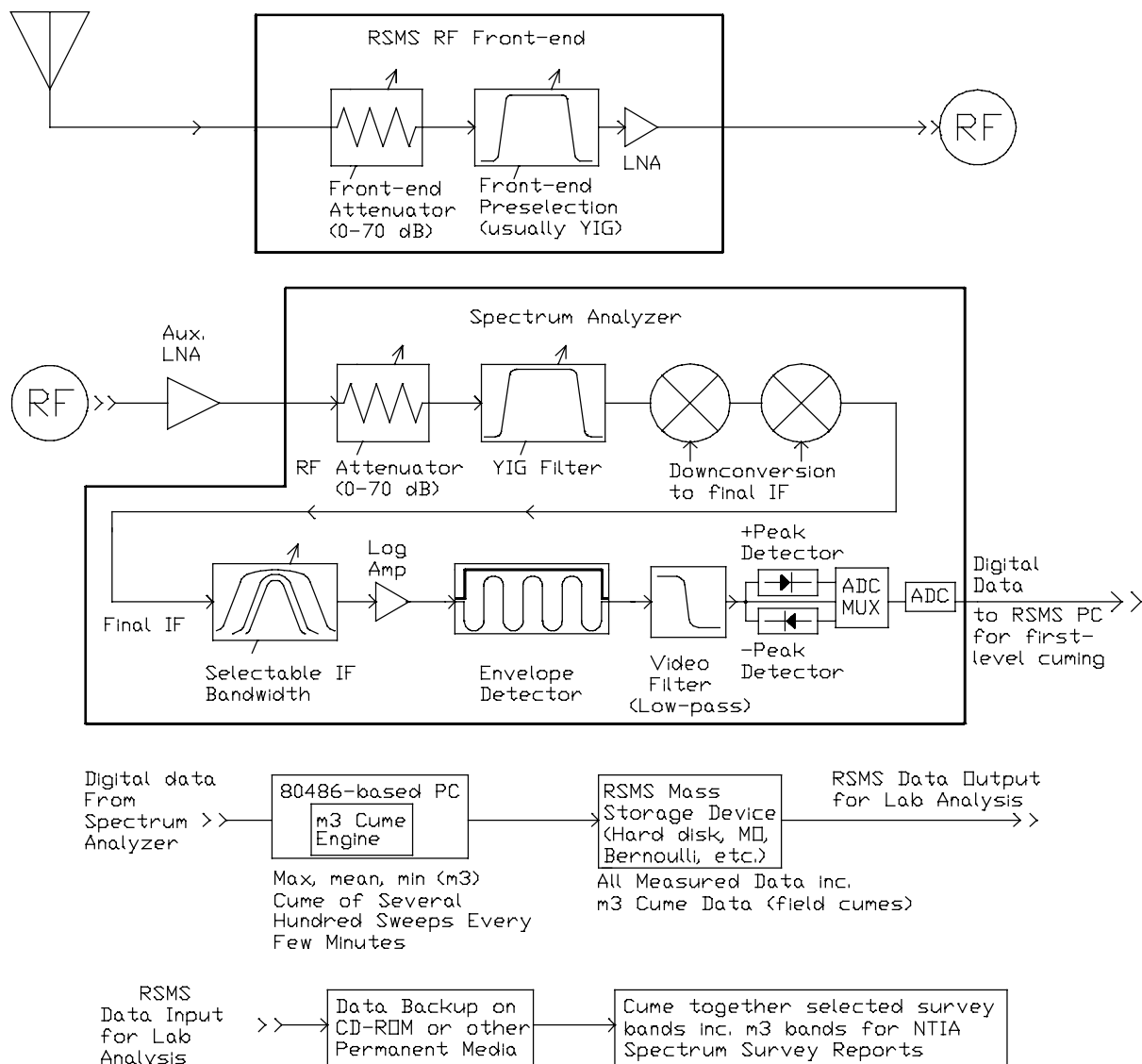


Figure B-1. Functional diagram of the RSMS signal-processing path for measured data.

#### B.4.1 Interpretation of Noise Responses in Swept/m3/Sample Data

The noise level displayed by a measurement system using the sample detector will be equal to  $[kTB + (\text{measurement system noise figure})]$ .<sup>3</sup> With a 1-MHz IF bandwidth and a 10-dB measurement system noise figure, for example, the average noise level would occur at -104 dBm.

<sup>3</sup> $kTB$  is derived from the Nyquist Theorem for electron thermal noise, where:  $k$  is Boltzmann's constant ( $1.38 \times 10^{-20}$  mW  $\times$  s/K),  $T$  is system temperature (290 K for these measurements), and  $B$  is measurement IF bandwidth in Hz. For  $B = 1$  Hz, at room temperature:  $kTB = -174$  dBm. In a 1-MHz IF bandwidth,  $kTB = -174 + 10\log(10^6) = -114$  dBm.

If the video bandwidth (that is, the postenvelope detector, low-pass filtering bandwidth) is significantly narrower than the IF bandwidth, then the variance in the measured average noise will be very small (approximately 1 dB). This mode normally is used only for calibrations in the RSMS.

However, if the video bandwidth is set to a value equal to or greater than the IF bandwidth (which is the case for RSMS spectrum survey measurements), then the maximum level sampled on thermal noise will be about 10 to 12 dB above the average, and the minimum level sampled on thermal noise will be about 10 to 20 dB below the average.

#### **B.4.2 Interpretation of Signal Responses in Swept/m3/Sample Data**

Because the sample detector value displayed for each bin is the value of the waveform at the end of each bin interval, the value displayed for a signal with a duty cycle of 100% will be equal to the peak power of the signal (if the signal was present for the entire bin interval). However, if a signal has less than a 100% duty cycle (and is not present during the entire bin interval), then the probability that the signal will be sampled is less than 1. For example, if the signal is only present for half of the bin interval, there is only a 50% chance that the sample detector will capture the value of the signal (and a 50% chance that the measurement system's thermal noise will be displayed). For typical radar signals, which operate with a duty cycle of about 1:1000, the probability that a bin will display the radar signal value is only about 1/1000 (0.1%). The same rationale holds for impulsive noise; sample detection mode tends to display high-duty cycle signals, but not low-duty cycle signals such as radars and impulsive noise. This makes sample detection a desirable option for measurements in bands handling mobile communications, where the signals of interest have high duty cycles, and where measurement of impulsive noise is not desirable for the purposes of the RSMS project.

For swept/m3/sample data, the highest curve shows the maximum signal ever captured by the sample detector on any trace at each measured frequency. This represents the highest value ever attained by high-duty cycle signals at each measured frequency; impulsive energy could have been present at even higher values, but would have been discriminated against by the sample detector. At frequencies where no signal was ever measured, the maximum curve will have a value of  $kTB$  + measurement system noise figure + (typically) 10 dB. This value will be 10 dB higher than the average noise (middle) curve. Since a signal displayed on the maximum curve can occur with different amplitudes at different times, there is no way to determine, solely from examination of the maximum curve, how frequently the displayed signals were measured.

The middle curve of swept/m3/sample data shows the power average (average of the measured decibel values) of all of the raw data traces gathered in the band. Qualitatively, the closer this curve comes to the maximum curve at any given frequency, the higher the percentage of scans in which the signal was observed. Quantitatively, it is not possible to derive an actual percentage of scans in which the signal was present. This is because the signal may not always have been received at the same level, and the level received on raw scans is not recorded. If, however, the average curve comes close to touching the maximum curve, then the signal must have been present in nearly 100% of the raw data traces. Conversely, if the maximum and mean curves are

far apart, then the signal probably was observed in a lower percentage of raw data scans. If no signals were ever measured at any given frequency, then the middle curve will show measurement system noise at a value of  $kTB$  + measurement system noise figure (about 10 dB below the maximum noise curve).

Finally, the lowest curve shows the minimum power level measured in any raw data trace, at each measured frequency bin. If no signal is measured in a bin during any sweep, then this curve will have a value of:  $kTB$  + measurement system noise figure – (10 to 20 dB). This is 10 to 20 dB lower than the average curve. If a signal is present in 100% of the measurement sweeps, then a bump will occur in the minimum curve at that frequency. The amplitude of the bump will be equal to the minimum power measured for the signal. Thus, this curve serves the purpose of showing signals that are continuously present during the spectrum survey.

In this report, the nominal levels of the measurement system noise for the maximum, minimum, and mean curves are indicated by labeled tick marks on the y-axis of each swept/m3/sample graph. The tick marks, labeled "max sample noise," "mean sample noise," and "min sample noise," are intended to assist report users in determining which graphed features are signal responses and which graphed features are measurement system noise.

## **B.5 DESCRIPTION OF SWEPT/M3/+PEAK DATA COLLECTION**

If the swept/m3 algorithm is performed using the positive peak (+peak) detector (see Section B.3 for a description of the +peak detector in the RSMS spectrum analyzers), then the data are called "swept/m3/+peak."

### **B.5.1 Interpretation of Noise Responses in Swept/m3/+Peak Data**

The average noise level displayed by a measurement system using a +peak detector will be equal to  $kTB$  + measurement system noise figure + approximately 10-12 dB. With a 1-MHz IF bandwidth and a 10-dB measurement system noise figure, for example, the average +peak noise level would occur at  $-174 \text{ dBm/Hz} + 10\log(10^6 \text{ Hz}) + 10\text{-dB noise figure} + 10\text{-dB peak detector offset} = -94 \text{ dBm}$ .

If the video bandwidth (the postenvelope detector, low-pass filtering bandwidth) is equal to or greater than the IF bandwidth (which is the case for RSMS site survey measurements), and if the sweep time is short (a few tens of microseconds per bin), then the maximum level sampled on thermal noise will be about 10 dB above the average; the minimum level of thermal noise will be about 10 dB below the average. Note that this  $\pm 10\text{-dB}$  value for maximum and minimum levels of +peak noise is the same as the  $\pm 10\text{-dB}$  offset levels for sample detection; however the maximum, mean, and minimum peak-detected levels are 10 dB higher than the corresponding sample-detected levels.

Positive peak detection shows less than a  $\pm 10\text{-dB}$  difference between the maximum, mean, and minimum as sample times increase (i.e., as sweep times become longer). This is because the

positive peak detector will have a higher probability of latching to a high noise level if it samples the noise for a relatively long interval. In this case, the minimum and average noise levels will approach the maximum noise level to within a few decibels. The maximum will be 2 to 3 dB higher than the short sweep-time values.

### **B.5.2 Interpretation of Signal Responses in Swept/m3/+Peak Data**

Because the +peak detector latches to the highest value that the waveform assumes during each bin interval, the value displayed for a signal will be equal to the peak power of the signal (assuming that the measurement system is not bandwidth-limited in its response) regardless of the signal's duty cycle. This makes +peak detection mode useful for measuring impulsive activity such as radar signals. (This means that +peak detection also will record impulsive noise in the spectrum.) Thus, the +peak detector is used in RSMS spectrum surveys to measure radiolocation bands and other bands where activity is dominated by impulsive (low-duty cycle) transmissions.

For swept/m3/+peak data, the highest curve shows the maximum signal ever captured by the +peak detector on any trace in each measured frequency bin. At frequencies at which no signal was ever measured, the maximum curve will have a value of  $kTB$  + measurement system noise figure + about 10-dB peak detector offset + 10 dB. If the sweep time is short (a few tens of microseconds per bin), this will be about 10 dB higher than the average peak detector response. If the sweep time is much longer, the average will be higher, coming to within a few dB of the maximum. There is no way to determine, solely from examination of the maximum curve, how frequently the displayed signals were observed.

The middle curve of swept/m3/+peak data shows the power average (average of the antilogs of 1/10 the measured decibel values) of all the data traces that were gathered in the band. Qualitatively, the closer this curve comes to the maximum curve at any frequency, the higher the percentage of scans in which the signal was observed. Quantitatively, it is not possible to derive a percentage of time the signal was present, because the signal may not always be received at the same level. If, however, the average curve nearly touches the maximum curve, then the signal must have been present in nearly all of the raw data traces. Conversely, if the maximum and mean curves are far apart, then the signal was probably observed in a low percentage of scans. If no signals were measured at a frequency, and if sweep time is a few tens of milliseconds, the middle curve will show measurement system noise at a value of  $kTB$  + measurement system noise figure + about 10-dB peak detector offset. This value will be nearly 10 dB higher if the sweep time is appreciably longer.

Finally, the lowest curve shows the minimum power level measured with the +peak detector in any sweep, in each frequency bin. If no signal is measured at a frequency, and if the sweep time is a few tens of milliseconds, this curve will have a value of:  $kTB$  + measurement system noise figure + about 10-dB peak detector offset - 10 dB, which is 10 dB lower than the mean peak detector curve. If the sweep time is longer, the minimum curve will approach the maximum and mean curves. If a signal is observed at a frequency in every data sweep, then a bump will occur



in the minimum curve at that frequency. Thus, this curve shows signals that are present continuously during the spectrum survey.

In this report, the nominal levels of the measurement system noise for the maximum, minimum, and mean curves are indicated by tick marks on the y-axis of each swept/m3/+peak graph. The tick marks, labeled "max +peak noise," "mean +peak noise," and "min +peak noise," are intended to assist report users in determining which graphed features are detected signals and which graphed features are measurement system noise.

## **B.6 DESCRIPTION OF SWEPT/MAX-HOLD DATA COLLECTION**

If a frequency-sweeping algorithm is performed using the +peak detector (see Section B.3 for a description of the +peak detector in the RSMS spectrum analyzers) while the spectrum analyzer display is being operated in the Maximum-Hold mode,<sup>4</sup> then the data are referred to as "swept/max-hold."

The measured data are peak-detected, maximum-hold scans. Each scan represents an interval of a few minutes of maximum-hold running on the measurement system. The scans do not contain mean or minimum information. They are intended only to show the presence of intermittent, low-duty cycle signals, and therefore no additional information is obtained.

The individual scans are cumed for the site survey report, and as a result, the final graphs show maximum, minimum, and mean curves. However, the distribution of maximum-hold data is narrow when noise is being measured, and so the difference between these curves is only about  $\pm 3$  dB on noise, instead of the  $\pm 10$  dB difference which usually characterizes swept/m3 data.

### **B.6.1 Interpretation of Noise Responses in Swept/Max-Hold Data**

The maximum, mean, and minimum curves displayed by a measurement system will be nearly identical if the hold time is more than a few tens of microseconds per bin. If white noise is measured, the three curves will all have a value of about  $kTB$  (at room temperature) + measurement system noise figure + about 10-dB peak detector offset + 10 dB. With a 1-MHz IF bandwidth and a 10-dB measurement system noise figure, for example, the noise level is about  $-174 \text{ dBm/Hz} + 10\log(10^6 \text{ Hz}) + 10\text{-dB noise figure} + 10\text{-dB peak detector offset} + 10 \text{ dB} = -84 \text{ dBm}$ .

If the video bandwidth is equal to or greater than the IF bandwidth, then the maximum level sampled on thermal noise in maximum-hold mode is empirically observed to limit at about 2 dB

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<sup>4</sup>In Maximum-Hold mode, the spectrum analyzer repeatedly sweeps a portion of spectrum, and saves the highest value measured in any sweep in each screen display bin. Thus, Maximum-Hold mode generates a maximum-level trace which is analogous to the maximum-level trace generated by RSMS software in the Swept/m3/+peak mode.

above the mean of the maximum, and the minimum level sampled on thermal noise is about 2 dB below the mean of the maximum.

### **B.6.2 Interpretation of Signal Responses in Swept/Max-Hold Data**

Swept/max-hold measurement mode is ideal for capturing low-duty cycle signals from intermittently operating systems. It can be used in bands occupied by impulsive emitters that operate intermittently (e.g., airborne radars). A swept/max-hold measurement displays the maximum activity observed in a band for an interval of a few minutes. No information is collected to indicate mean or minimum activity during that interval.

For cumed swept/max-hold data, the highest curve shows the maximum signal ever captured by the +peak detector on any maximum-hold trace at each measured frequency. Since a signal displayed on the maximum curve could have occurred with different amplitudes at different times, there is no way to determine, solely from examination of the maximum curve, how frequently the displayed signals were actually observed.

The middle curve of cumed swept/max-hold data shows the power-average (average of the antilogs of 1/10 the measured decibel values) of all individual maximum-hold data traces that were measured in the band. Qualitatively, the closer this curve comes to the maximum curve at a frequency, the higher the percentage of scans in which the signal was observed. Quantitatively, it is not possible to derive an actual percentage of time that the signal was present, because the signal may not have always been received at the same level. If the mean curve nearly touches the maximum curve, then the signal must have been present in most of the raw data traces. If no signals were ever measured at any given frequency, then the middle curve will be about 3 dB lower than the maximum curve.

Finally, the lowest curve shows the minimum power level ever measured with the +peak detector in any maximum-hold data trace, at each measured frequency. If a signal was present in every scan, then the curve shows a bump at that frequency. Otherwise, the curve will show noise 3 dB below the mean curve. Thus, this curve shows signals that were present in all of the scans.

## **B.7 DESCRIPTION OF STEPPED/+PEAK DATA COLLECTION**

Although most spectrum analyzers routinely are operated by sweeping in the frequency domain, this is not the most efficient method for measuring spectral emissions from pulsed emitters like radars. An alternative method, called stepping, is usually faster and can provide measurement results with wider dynamic range than is possible with sweeping.

Stepping is performed by tuning the measurement system to a frequency and then performing a time-scan at that frequency over a span of zero hertz. In this mode, the spectrum analyzer makes 1001 measurements at equally spaced time intervals during the selected scan time. Positive peak detection is always used. For rotating radars, the interval (called dwell time) for a single time-scan is set equal to or greater than the radar rotation time. (For electronically beam-scanning

radars, this interval is selected on the basis of the typical recurrence of the radar beam at the measurement site.) For example, if a radar has a 10-s rotation time, then the dwell time at each measured frequency might be set to 12 s. Thus, the emitter's rotating main beam certainly would be aimed in the direction of the measurement system at some moment during the 12-s time scan. At the end of the dwell period, the highest-amplitude point that was measured is retrieved, corrected for calibration factors, and stored. This process of waiting at a frequency in a 0-Hz span and recording the highest point measured during a radar rotation (or beam-scanning) interval is called a "step." When each step is completed, the measurement system is tuned to another, higher frequency, and the process is repeated. Attenuation can be added or subtracted at the RSMS signal input at each measurement step. Thus, the instantaneous dynamic range of the RSMS, (normally about 60 dB) can be augmented by the amount of input attenuation that is selected. Maximum available attenuation is 50-70 dB (depending upon which frontend is selected), giving a total RSMS measurement range of about 110-130 dB.

The spectrum interval between adjacent measured frequencies is approximately equal to the IF bandwidth of the measurement system. For example, if a 1-MHz IF bandwidth is being used, then the frequency interval between steps will be about 1 MHz. The IF bandwidth is determined from the inverse of the emitter pulse width. For example, if 1  $\mu$ s is the shortest pulse width expected from emitters in a band, then a 1-MHz measurement (IF) bandwidth is used. In this manner, the measurement system progressively tunes across the band of interest.

Stepped measurements are used for all dominantly radiolocation (radar) bands. IF bandwidth and dwell times are optimized for typical radars in the band. The individual stepped measurement scans are cumed for spectrum surveys and the final graphs show a maximum, minimum, and mean value for each dwell time at each measured frequency during the entire survey.

### **B.7.1 Interpretation of Noise Responses in Stepped/+Peak Data**

The mean noise level displayed by the measurement system in the +peak detector stepped mode will be equal to  $kTB$  (at room temperature) + measurement system noise figure + 10-dB peak detector offset. With a 1-MHz IF bandwidth and a 10-dB measurement system noise figure, for example, the mean +peak noise level is  $-174 \text{ dBm/Hz} + 10\log(10^6 \text{ Hz}) + 10\text{-dB noise figure} + 10\text{-dB peak detector offset} = -94 \text{ dBm}$ .

The difference between the maximum and minimum levels measured for noise in the stepped mode is small; the maximum and minimum curves will be about  $\pm 2 \text{ dB}$  relative to the mean curve.

### **B.7.2 Interpretation of Signal Responses in Stepped/+Peak Data**

Stepped/+peak measurement mode is ideal for capturing low-duty cycle signals from systems that direct energy at the measurement site at regular intervals (e.g., rotating radars). If the dwell time is greater than or equal to the rotation time of the radar, then the stepped algorithm will fill the emission envelope completely.

The maximum curve on each site survey graph for stepped measurements depicts the maximum envelope of the spectral emissions of the emitters observed in the band. The result is a representation of the spectrum occupancy when emissions (usually radar beams) are directed at the measurement site.

The minimum curve represents the lowest signal ever measured at each frequency step during the survey. If an emitter is turned off during a single scan, then this curve will be at the system noise level for that emitter. At frequencies where this curve is above the noise level, but well below the maximum curve, the difference represents either varying emitter power output levels, varying emitter-scanning modes, varying propagation between the emitter and the measurement site, or a combination of these factors.

The mean curve represents the mean power (the average of the antilogs of 1/10 the decibel values of received signal level) for each frequency step in the band of interest during the site survey. This is not necessarily the same as the mean signal level transmitted by a radar to the measurement location. For example, a radar that was turned on during half the stepped scans, and turned off during the other half would appear, after cuming, with a maximum curve that is its emission envelope, a minimum curve that is the measurement system noise floor, and a mean curve roughly 3 dB below the radar envelope. However, the radar might never have been measured at the amplitudes shown on the mean curve.

## **B.8 DESCRIPTION OF SWEPT/AZ-SCAN DATA COLLECTION**

In bands dominated by point-to-point fixed microwave communication systems, the transmitter main beams are seldom pointed towards the RSMS. To enhance the probability of intercepting low-level sidelobe and backlobe signals from these sources, a high-gain parabolic reflector with a linear horizontal and vertical cross-polarized feed antenna is used. However, the site survey data must include signals received from all points on the horizon; so, azimuth-scanning with the parabolic reflector (dish) antenna is performed. The RSMS dish is pointed at the horizon and slowly rotated through 360°. Simultaneously, a spectrum analyzer sweeps the band of interest with positive peak detection and maximum-hold scan mode. Such measurements are called "swept/az-scan."

The dish antenna is rotated at approximately 6°/s (1 rpm), while the sweep time across the band is set at 20 ms. At the highest frequencies, where the dish beamwidth is about 1°, the dish rotates through one beamwidth in 1/6 s (170 ms). This is long enough for 7 or 8 sweeps (170 ms/20 ms) within the beam width. Thus, every point on the horizon is sampled at least 7 or 8 times across the entire band of interest. Maximum-hold mode and positive peak detection ensure that any signal that arrives at the RSMS site is retained on the scan.

The dish is rotated twice around the horizon: once with horizontal polarization and once with vertical polarization. The purpose is to observe point-to-point linked signals of either polarization. The two polarization scans are combined to show the maximum envelope of both scans on a single data curve.

The single data curve is corrected for noise diode calibration factors and recorded. Unlike other RSMS site survey measurements, this measurement is performed only once at each survey location and no cuming is performed on this data. Activity in these bands does not vary much with time and little information is gained by measuring these bands repetitively.

### **B.8.1 Interpretation of Signal Responses in Swept/Az-Scan Data**

Swept/az-scan data show the presence of a signal at some point or points on the horizon. The data curve does not reveal the direction of any signals, but does show the aggregate occupancy of the spectrum by all point-to-point signals detected omnidirectionally on the horizon.

Generally, two types of signals will be noted in the az-scan graphs: those having narrow emission spectra, and those having wider emissions. The narrow signals are analog links, and the wider signals are digital links. Because a single transmitting tower (a single point on the horizon) may have many channels in operation (often located next to each other in the spectrum), clusters of signals with uniform amplitudes will be observed. Space-to-earth and earth-to-space links in these bands normally are not detected by the RSMS.